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ABSTRACT

Listed are metric and other units and symbols used in the energy field. It can be used to aid in solving problems such as correct spelling, punctuation, and capitalization of such units and symbols. There are no conversion tables or formulas. Also included are suggestions about modifying symbols for use in data processing systems that lack the necessary character sets. (MP)

DOE/EIA-0038

The U.S. Department of Energy Guide to Selected Metric (SI) Units and Symbols

April 1978

United States
Department of Energy

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The U.S. Department of Energy Guide to Selected Metric (SI) Units and Symbols

April 1978

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Energy Information Administration
Office of Energy Data and Interpretation
Interfuels Statistics Division
Washington, DC 20461

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Preface

While the following list is extensive, it is by no means comprehensive. It is to be regarded solely as a reference tool, enabling those who use it to quickly solve such fundamental but vital problems as correct spelling, punctuation, and capitalization of energy-related metric (SI) units, derived units, and symbols. No attempt has been made to metricize—i.e., to convert any unit to its metric (SI) equivalent—or vice versa—i.e., to convert a metric unit to any other unit.

Included with the list are suggestions about how some of these units and their symbols can be modified for use in those data processing systems where character sets lack the necessary SI members and where the system output is interpreted by human beings, along with the very concise October 26, 1977, National Bureau of Standards *Federal Register* notice concerning United States adoption of SI standards.

SI AND OTHER UNITS AND SYMBOLS USED IN THE ENERGY FIELD

Unit of measure	*Symbol*
ampere	A
ampere per meter	A/m
ampere per square meter	A/m^2
angstrom[a]	Å
atto $(10^{-18})^b$	a
bar[a]	bar
barn[a]	b
barrel[a]	bbl
barrel per day[a]	bbl/d
becquerel	Bq
British thermal unit[a]	Btu
calorie[a]	cal
candela	cd
candela per square meter	cd/m^2
centi $(10^{-2})^b$	c
centimeter	cm
centipoise[a]	cP
centistokes[a]	cSt
cheval vapeur[a]	cv
cheval vapeur hour[a]	cv·h
coulomb	C
coulomb per cubic meter	C/m^3
coulomb per square meter	C/m^2
cubic centimeter	cm^3
cubic decimeter	dm^3
cubic foot[a]	ft^3
cubic meter	m^3
cubic meter per hour	m^3/h
cubic meter per kilogram	m^3/kg
cubic meter per second	m^3/s
curie[a]	Ci
darcy	D
day	d
deci $(10^{-1})^b$	d

See footnotes at end of list.

Unit of measure	*Symbol*
degree (plane angle)	°
degree Celsius	°C
degree centigrade[a]	°C (See degree Celsius)
degree Fahrenheit[a]	°F
degree Kelvin[a]	°K (Use kelvin)
degree Rankine	°R
deka (10^1)[b]	da
dyne[a]	dyn
erg[a]	erg
exa (10^{18})[b]	E
farad	F
farad per meter	F/m
femto (10^{-15})[b]	f
foot pound-force[a]	ft·lbf
gallon[a]	gal
gallon per minute[a]	gal/min
gauss[a]	G
giga (10^9)[b]	G
gigabecquerel	GBq
gigacalorie[a]	Gcal
gigagram	Gg
gigajoule	GJ
gigaliter[c]	GL
gigawatt	GW
gigawatthour	GWh
gram	g
gram per kilogram	g/kg
gray	Gy
hectare	ha
hecto (10^2)[b]	h
hectoliter[c]	hL
henry	H
henry per meter	H/m
hertz	Hz
horsepower[a]	hp
horsepower hour[a]	hp·h

See footnotes at end of list.

Unit of measure	*Symbol*
hour	h
joule	J
joule per cubic meter	J/m^3
joule per kelvin	J/K
joule per kilogram	J/kg
joule per kilogram kelvin	J/(kg·K)
joule per mole	J/mol
joule per mole kelvin	J/(mol·K)
kelvin	K
kilo (10^3)[b]	k
kiloampere	kA
kilobarrel[a]	kbbl
kilocalorie[a]	kcal
kilogauss[a]	kG
kilogram	kg
kilogram meter per second	kg·m/s
kilogram square meter	$kg·m^2$
kilogram per cubic meter	kg/m^3
kilogram per meter	kg/m
kilogram per meter second	kg/(m·s)
kilogram per second	kg/s
kilogram per second meter	kg/(s·m)
kilogram per square meter	kg/m^2
kilohertz	kHz
kilohm	kΩ
kilojoule	kJ
kilojoule per square meter	kJ/m^2
kiloliter[c]	kL
kilonewton	kN
kilopascal	kPa
kilotonne[a]	kt (See metric kiloton)
kilovolt	kV
kilowatt	kW
kilowatthour	kWh
langley[a]	L
liter[d]	L

See footnotes at end of list.

Unit of measure	*Symbol*
lumen	lm
lux	lx
mega $(10^6)^b$	M
megacalorie[a]	Mcal
megacalorie per kilogram[a]	Mcal/kg
megagram	Mg
megahertz	MHz
megajoule	MJ
megajoule per kilogram	MJ/kg
megaliter[c]	ML
megapascal	MPa
megavolt	MV
megawatt	MW
megawatthour	MWh
megohm	MΩ
meter[d]	m
meter newton	m·N
meter per second	m/s
meter per second squared	m/s^2
metric kiloton	kt (Same size as gigagram)
metric ton	t (Same size as megagram)
mho[a]	mho (Use siemens)
micro $(10^{-6})^b$	μ
microfarad	μF
microjoule	μJ
micrometer	μm
micronewton	μN
microwatt	μW
milli $(10^{-3})^b$	m
millibar[a]	mbar
millicoulomb per kilogram	mC/kg
millidarcy[a]	mD
milligram	mg

See footnotes at end of list.

Unit of measure	*Symbol*
milligram per kilogram	mg/kg
milligray	mGy
millihenry	mH
milliliter	mL
millimeter	mm
millimeter squared per second	mm^2/s
millinewton	mN
millipascal second	mPa·s
millitesla	mT
milliwatt	mW
minute (plane angle)	′
minute (time)	min
mole	mol
mole per cubic meter	mol/m^3
nano $(10^{-9})^b$	n
nanometer	nm
newton	N
newton meter	N·m
newton meter per radian	N·m/rad
newton meter per second	N·m/s
newton per meter	N/m
ohm	Ω
pascal	Pa
pascal second	Pa·s
peta $(10^{15})^b$	P
pico $(10^{-12})^b$	p
picoliter per meter[c]	pL/m
poise[a]	P
pound[a]	lb
pound-force[a]	lbf
pound-force per square inch[e]	psi or lbf/in^2
pound-force per square inch absolute[e]	psia
pound-force per square inch gauge[e]	psig
quad[a]	q
radian	rad
radian per second	rad/s
radiation absorbed dose[a]	rd
reciprocal meter (wavelength)	m^{-1}

See footnotes at end of list.

Unit of measure	*Symbol*
relative biological effectiveness[a]	RBE
revolution per minute[a]	r/min
revolution per second	r/s
roentgen[a]	R
roentgen equivalent man[a]	rem
second (plane angle)	"
second (time)	s
siemens	S
square kilometer	km^2
square meter	m^2
steradian	sr
stokes[a]	St
tera (10^{12})[b]	T
teracalorie[a]	Tcal
terajoule	TJ
terajoule per year	TJ/a or TJ/yr
teraliter[c]	TL
terawatt	TW
terawatthour[a]	TWh
tesla	T
therm[a]	thm
thermie[a]	th
ton (long)[a]	lt or long ton
ton (short)[a]	st or short ton
tonne[a]	t (See metric ton)
torr[a]	Torr
trillion cubic feet[a]	tcf
volt	V
volt ampere	V·A
volt per meter	V/m
watt	W
watthour	Wh
watt per cubic meter	W/m^3

See footnotes at end of list.

Unit of measure	Symbol
watt per meter kelvin	W/(m·K)
watt per square meter	W/m^2
watt per square meter steradian	$W/(m^2 \cdot sr)$
weber	Wb
year	a or yr

Footnotes

[a] All units designated by footnote[a] are either to be used for a limited time only, are obsolete, or are being replaced by units of the International System (SI). All those not designated by footnote[a] are SI units or units in use with SI. For a listing of SI units, see the attached reprint of the NBS October 26, 1977, *Federal Register* notice.

[b] This and the 15 other prefixes herein listed, designated by a footnote[b], are used to form multiples and submultiples of SI units. Prefixes are never to be used alone.

[c] Usage of this term is not recommended by American National Standard Z210.1-76. No prefix other than milli should be used with the unit "liter."

[d] The unit "liter" presents a special problem. To avoid confusing the lowercase "l," which is the international symbol for liter, with the numeral "1," the symbol "L" is recommended for United States use. The U.S. Department of Commerce recommends the spelling "meter" and "liter" for all Government agencies and for the private sector. The variant spellings "metre" and "litre" are also used, especially in British English.

[e] There are no proper symbols for these units. Instead, the abbreviations psi or lbf/in^2, psia, and psig are used.

SUGGESTIONS FOR ADAPTING SI UNITS AND SYMBOLS FOR USE IN DATA PROCESSING SYSTEMS WITH LIMITED CHARACTER SETS

The following symbols are to be used *only* when a limited set of characters is available to express the unit symbols. They must not be used when the available character set would permit the use of the

proper standard symbols. These symbols are intended for use by human beings, not by computers.[a]

When Character Set Lacks Greek Letters:

(a) For symbol μ substitute u (example: μA symbol for microampere becomes uA); in typewritten text or masters prepared for photoreproduction add a "tail" on the left by hand (example: μA symbol for microampere becomes μA);

(b) For symbol Ω substitute Ohm (example: kΩ symbol for kilohm becomes kOhm).

When Character Set Lacks Superscript Symbols:

(a) For °C, °F, °R, substitute C, F, and R (example: 12 degrees Celsius becomes 12 C);

(b) For units of plane angle substitute the following abbreviations:

deg for (°) degree
min for (′) minute
sec for (″) second

When Character Set Lacks Superscript Numerals:

Use numbers on the line (example: mm^2 symbol for square millimeter becomes mm2; W/m^2 symbol for watt per square meter becomes W/m2 or W/m−2; m^{-3} for per cubic meter becomes m−3). When expressing a negative exponent use a solidus (example: $m \cdot s^{-1}$ for meter per second becomes m/s).

When Character Set Lacks Raised Dot:

Use dot on the line (period) to indicate multiplication of unit (example: N·m symbol for newton

[a] For further information, see "Part II: Symbols to be Used With Limited Character Sets," IEEE Standard 260-1977 (New York, Institute of Electrical and Electronics Engineers, Inc., 1977).

meter becomes N.m; Pa·s symbol for pascal second becomes Pa.s).

When Character Set is Limited to a Single Case:

(a) Write symbols in single case available, whether uppercase or lowercase; the context nearly always makes author's intention clear (example: M or m for mega- and milli-; MW or mw for megawatt and milliwatt; P or p for pico- and peta-; S or s for second [time] and siemens, and T or t for tesla and metric ton).

(b) When context alone does not make the author's intention clear, write the unit name in full.

When Indicating Division of Units:

Separate numerator and denominator by a solidus (/) or express denominator with a negative exponent (example: meter per second becomes m/s or $m \cdot s^{-1}$; kilonewton per square meter becomes kN/m^2 or $kN \cdot m^{-2}$).

Note: In data processing, as elsewhere, it is recommended that numbers with four or more digits be placed in groups of three separated by a space instead of a comma, counting from both the left and the right of the decimal point, in order to avoid the confusion which results from the European custom of using commas to express decimal points (example: 389 967.618 87 for 389,967.61887).

THE METRIC SYSTEM OF MEASUREMENT (SI)

FEDERAL REGISTER NOTICE
of
OCTOBER 26, 1977

This NBS Letter Circular reproduces the Federal Register notice that interprets and modifies the International System of Units (SI), the Modernized

Metric System, for the United States. This notice supersedes a similar notice dated December 10, 1976.

Also included is a chart that shows the relationships of all the SI units to which names have been assigned.

Office of the Secretary

THE METRIC SYSTEM OF MEASUREMENT

Interpretation and Modification of the International System of Units for the United States

Section 3 of Pub. L. 94–168, the Metric Conversion Act of 1975, declares that the policy of the United States shall be to coordinate and plan the increasing use of the metric system in the United States. Section 403 of Pub. L. 93–380, the Education Amendments of 1974, states the policy of the United States to encourage educational agencies and institutions to prepare students to use the metric system of measurement as part of the regular education program. Under both these acts, the "metric system of measurement" is defined as the International System of Units as established by the General Conference on Weights and Measures in 1960 and interpreted or modified for the United States by the Secretary of Commerce (subsec. 4(4), Pub. L. 94–168; subsec. 403(a)(3), Pub. L. 93–380). The Secretary has delegated her authority under these subsections to the Assistant Secretary for Science and Technology. In implementation of this authority, tables and associated materials were published in the FEDERAL REGISTER of December 10, 1976 (41 FR

54018), setting forth the interpretation and modification of the International System of Units (hereinafter "SI") for the United States.

In accordance with recent decisions of the International Committee for Weights and Measures of the General Conference on Weights and Measures, and to refine the earlier interpretation and modification, it is deemed appropriate to amend that interpretation and modification, as published in the above-cited FEDERAL REGISTER notice of December 10, 1976. To assist interested parties and encourage the proper use of SI, the entire interpretation and modification, as hereby amended, is republished. Accordingly, this notice supersedes the notice of December 10, 1976.

The amendments include the addition in Table 2 of the degree Celsius as an SI derived unit with a special name, and, also in Table 2, more precise descriptions of the quantities for the becquerel and the gray. There are two additions to Table 4 of SI derived units expressed by means of special names. The amendments are indicated by a dagger symbol (†).

The SI is constructed from seven base units for independent quantities plus two supplementary units for plane angle and solid angle, listed in Table 1.

TABLE 1.—*SI base and supplementary units*

Quantity	Name	Symbol
SI base units:		
length	meter	m
mass	kilogram	kg
time	second	s
electric current	ampere	A
thermodynamic temperature	kelvin	K
amount of substance	mole	mol
luminous intensity	candela	cd
SI supplementary units:		
plane angle	radian	rad

solid angle	steradian	sr

[1] "Weight" is the commonly used term for "mass."

Units for all other quantities are derived from these nine units. In Table 2 are listed 18 SI derived units with special names which were derived from the base and supplementary units in a coherent manner, which means, in brief, that they are expressed as products and ratios of the nine base and supplementary units without numerical factors.

TABLE 2.—*SI derived units with special names*

Quantity	SI unit		
	Name	Symbol	Expression in terms of other units
frequency	hertz	Hz	s^{-1}
force	newton	N	$kg \cdot m/s^2$
pressure, stress	pascal	Pa	N/m^2
energy, work, quantity of heat	joule	J	N·m
power, radiant flux	watt	W	J/s
quantity of electricity, electric charge	coulomb	C	A·s
electric potential, potential difference, electromotive force	volt	V	W/A
capacitance	farad	F	C/V
electric resistance	ohm	Ω	V/A
conductance	siemens	S	A/V
magnetic flux	weber	Wb	V·s
magnetic flux density	tesla	T	Wb/m^2
inductance	henry	H	Wb/A
luminous flux	lumen	lm	cd·sr
illuminance	lux	lx	lm/m^2
†Celsius temperature.[1]	degree Celsius.	°C	K
†activity (of a radionuclide)	becquerel	Bq	s^{-1}
†absorbed dose, specific energy imparted, kerma, absorbed dose index	gray	Gy	J/kg

[1] In addition to the thermodynamic temperature (symbol T), expressed in kelvins (see table 1), use is also made of Celsius temperature (symbol t) defined by the equation

$$t = T - T_o$$

where $T_o = 273.15$ K by definition. The unit "degree Celsius" is equal to the unit "kelvin," but "degree

Celsius" is a special name in place of "kelvin" for expressing Celsius temperature. A temperature interval or a Celsius temperature difference can be expressed in degrees Celsius as well as in kelvins.

All other SI derived units, such as those in tables 3 and 4, are similarly derived in a coherent manner from the 27 base, supplementary, and special-name SI units.

TABLE 3.—*Examples of SI derived units expressed in terms of base units*

Quantity	SI unit	Unit symbol
area	square meter	m^2
volume	cubic meter	m^3
speed, velocity	meter per second	m/s
acceleration	meter per second squared	m/s^2
wave number	1 per meter	m^{-1}
density, mass density	kilogram per cubic meter	kg/m^3
current density	ampere per square meter	A/m^2
magnetic field strength	ampere per meter	A/m
concentration (of amount of substance)	mole per cubic meter	mol/m^3
specific volume	cubic meter per kilogram	m^3/kg
luminance	candela per square meter	cd/m^2

TABLE 4.—*Examples of SI derived units expressed by means of special names*

Quantity	Name	Unit symbol
dynamic viscosity	pascal second	Pa·s
moment of force	newton meter	N·m
surface tension	newton per meter	N/m
power density, heat flux density, irradiance	watt per square meter	W/m^2
heat capacity, entropy	joule per kelvin	J/K
specific heat capacity, specific entropy	joule per kilogram kelvin	J/(kg·K)
specific energy	joule per kilogram	J/kg
thermal conductivity	watt per meter kelvin	W/(m·K)
energy density	joule per cubic meter	J/m^3
electric field strength	volt per meter	V/m
electric charge density	coulomb per cubic meter	C/m^3

electric flux density	coulomb per square meter.	C/m^2
permittivity	farad per meter	F/m
permeability	henry per meter	H/m
molar energy	joule per mole	J/mol
molar entropy, molar heat capacity	joule per mole kelvin	J/(mol·K)
†exposure (x and γ rays)	coulomb per kilogram	C/kg
†absorbed dose rate	gray per second	Gy/s

For use with the SI units there is a set of 16 prefixes (see table 5) to form multiples and submultiples of these units. It is important to note that the kilogram is the only SI unit with a prefix. Because double prefixes are not to be used, the prefixes of table 5, in the case of mass, are to be used with gram (symbol g) and not with kilogram (symbol kg).

TABLE 5.—*SI prefixes*

Factor	Prefix	Symbol
10^{18}	exa	E
10^{15}	peta	P
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{2}	hecto	h
10^{1}	deka	da
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f
10^{-18}	atto	a

Certain units which are not part of the SI are used so widely that it is impractical to abandon them. The units that are accepted for continued use in the United States with the International System are listed in table 6.

TABLE 6.—*Units in use with the international system*

Name	Symbol	Value in SI unit
minute (time)	min	1 min = 60 s
hour	h	1 h = 60 min = 3 600 s

day	d	1 d = 24 h = 86 400 s
degree (angle)	°	$1° = (\pi/180)$ rad
minute (angle)	′	$1' = (1/60)° = (\pi/10\,800)$ rad
second (angle)	″	$1'' = (1/60)'$ $\doteq (\pi/648\,000)$ rad
liter	L*	1 L = 1 $dm^3 = 10^{-3}$ m^3
metric ton	t	1 t = 10^3 kg
hectare (land area)	ha	1 ha = 10^4 m^2

*The international symbol for liter is the lowercase "l", which can easily be confused with the numeral "1". Accordingly, the symbol "L" is recommended for United States use.

In those cases where their usage is already well established, the use, for a limited time, of the units in table 7 is accepted, subject to future review.

TABLE 7.—*Units to be used for a limited time*

nautical mile	angstrom	gal [1]	rad [2]
knot	barn	curie	
standard atmosphere	bar	roentgen	

[1] Unit of acceleration. [2] Unit of absorbed dose.

Metric units, symbols, and terms that are not in accordance with the foregoing Interpretation and Modification are no longer accepted for continued use in the United States with the International System of Units. Accordingly, the following units and terms listed in the table of metric units in section 2 of the act of July 28, 1866, that legalized the metric system of weights and measures in the United States, are no longer accepted for use in the United States:

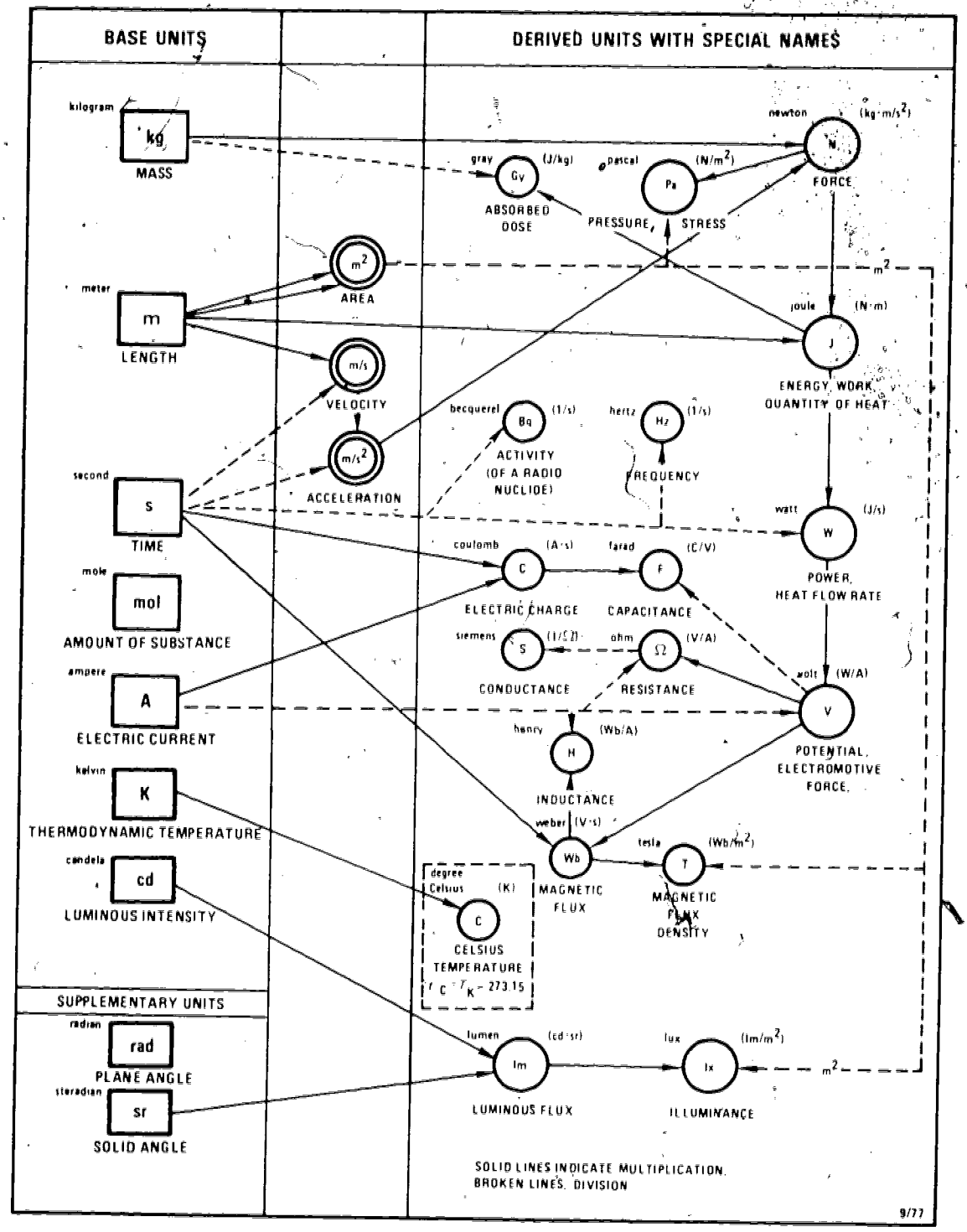
kilo (for kilogram)	myriagram
millier or tonneau	stere
quintal	myriameter

For more information regarding the International System of Units, contact the Office of Technical Publications, National Bureau of Standards, U.S. Department of Commerce, Washington, D.C. 20234.

JORDAN J. BARUCH,
Assistant Secretary for Science and Technology.

[FR Doc. 77-31094 Filed 10-25-77;8:45 am]

RELATIONSHIPS OF SI UNITS WITH NAMES



The chart on the FOLDOUT shows graphically how the 18 SI derived units with special names listed in Table 2 of the Federal Register Notice, reprinted below, are derived in a coherent manner from the base and supplementary units. In the first column the symbols of the base and supplementary units are shown in rectangles, with the name of the unit shown toward the upper left of the rectangle and the name of the quantity (measurable attribute) shown below the rectangle. In the third column the symbols of the derived units with special names are shown in solid circles, with the name of the unit shown toward the upper left of the circle, the name of the quantity shown below the circle, and an expression of the derived unit in terms of other units shown toward the upper right. In the second column are shown those derived units without special names that are used in the derivation of the derived units with special names. In the chart the derivation of each unit is indicated by arrows bringing in numerator factors (solid lines) and denominator factors (broken lines).

The degree Celsius, shown on the chart in a broken-line rectangle, is a special name for the kelvin, for use in expressing Celsius temperatures or temperature intervals. Where it is used to express temperature intervals, it is equal to the kelvin, as shown on the chart, with the symbol K toward the upper right of the °C circle; where it is used to express Celsius temperatures, the equation below "CELSIUS TEMPERATURE" relates Celsius temperature ($t_{°C}$) to thermodynamic temperature (T_K).

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